International Rectifier

APPLICATION NOTE

Application Note AN-1209

Using the IRS25751 High-Voltage Start-Up IC

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1. Introduction

The IRS25751 is a new uHVIC[TM] building block IC designed to provide easy and fast circuit start-up while enabling low circuit standby losses. Starting up a circuit is a standard function that is necessary for all types of power electronic circuits. This seemingly simple function can actually present several difficulties due to stringent standby losses and overall system efficiency requirements. This application note provides detailed information to help speed up design time and avoid circuit problems that can occur due to incorrect usage of the IC or noise susceptibility. Helpful information is included for understanding the functionality of the IC, how to use and program the IC, and how to properly design the PCB layout. An application example is also provided that includes the schematic, bill of materials, and circuit performance results.

2. Functional Description

The IRS25751 is designed to perform two main functions:

1) Turn on and provide a regulated output current from a high voltage bus for charging up the main VCC supply capacitor.
2) Turn off and block the high bus voltage while consuming ultra-low leakage current.

The IC is connected directly between the DC bus voltage node and the VCC supply node (Figure 1). The VIN pin connects to the DC bus, the VOUT pin connects to the VCC supply capacitor of the circuit (CVCC), and the COM pin connects to the circuit ground. An external voltage divider (R1, R2) is connected between VOUT, VTH and COM. The IC includes an internal 480V NMOS (HVFET) that sources a regulated current (IREG) from the VIN pin to the VOUT pin (Figure 1). The IC also includes an internal window comparator for turning the current source on and off. The external voltage divider (R1, R2), together with the internal threshold at the VTH pin, programs the upper turn-off threshold for the VOUT pin. An internal voltage divider circuit then sets the fixed lower turn-on threshold for VOUT. The IC also includes an enable pin (ENN) that can be used to turn off the current source. Finally, an over-temperature shutdown function with hysteresis is included to shut down and protect the IC should the die temperature exceed 155degC.

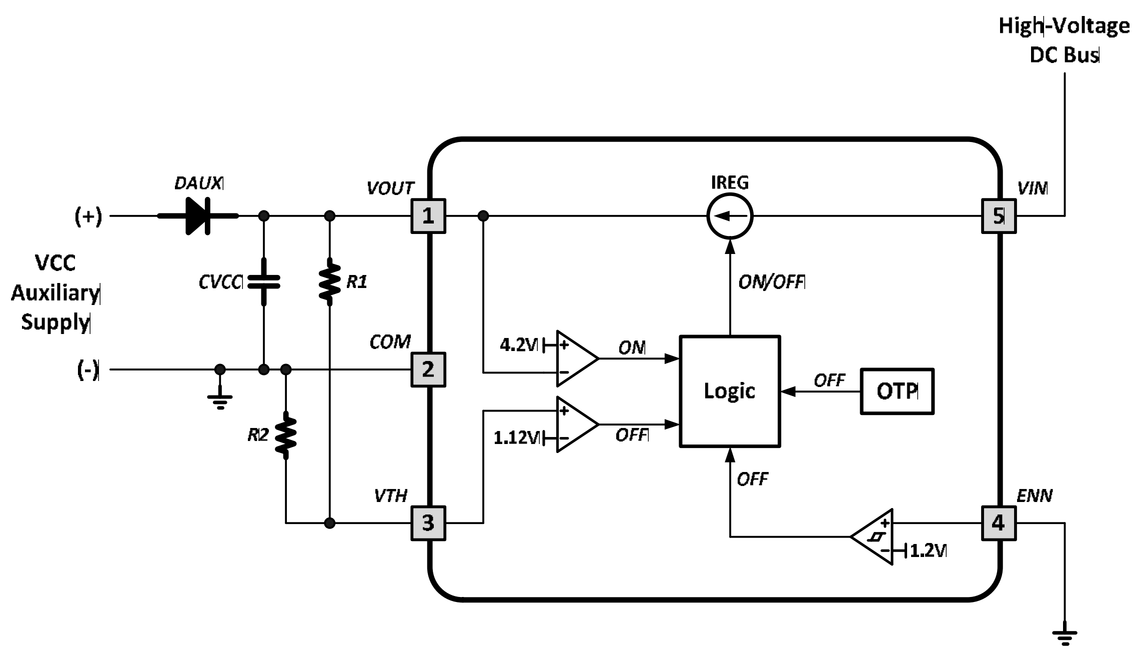

Figure 1: IC pin out and internal block diagram.

During the first turn-on period (Figure 2), the VIN and VOUT pins are both initially at zero. When the DC bus voltage of the circuit increases, the VIN pin voltage will increase and a small current will start to flow out of the VOUT pin. The CVCC capacitor at the VOUT pin will start to charge up. As the VIN pin voltage increases further, the output current will continue to increase and eventually reach the regulated output current level (IREG) when VOUT reaches approximately 100V. The VOUT pin voltage will continue to charge up at a rate determined by the CVCC capacitor value and the output current (IREG), minus any additional VCC current being consumed by the VCC circuit. The VOUT pin voltage will continue to charge up to the VOUT+ threshold (programmed at the VTH pin) and the current source turns off. At this time, the main circuit should start up and the auxiliary supply should take over through the auxiliary supply diode (Figure 1, DAUX). If the auxiliary supply does not take over and supply current to VCC then the VOUT pin voltage will start to discharge and will eventually reach the fixed VOUT- lower threshold (4.2V). At this time the current source will turn on again and VOUT will charge back up again to the programmed VOUT+ level. The current source will once again turn off and the auxiliary supply will take over and charge VOUT up further and maintain VOUT at a higher level fixed level.

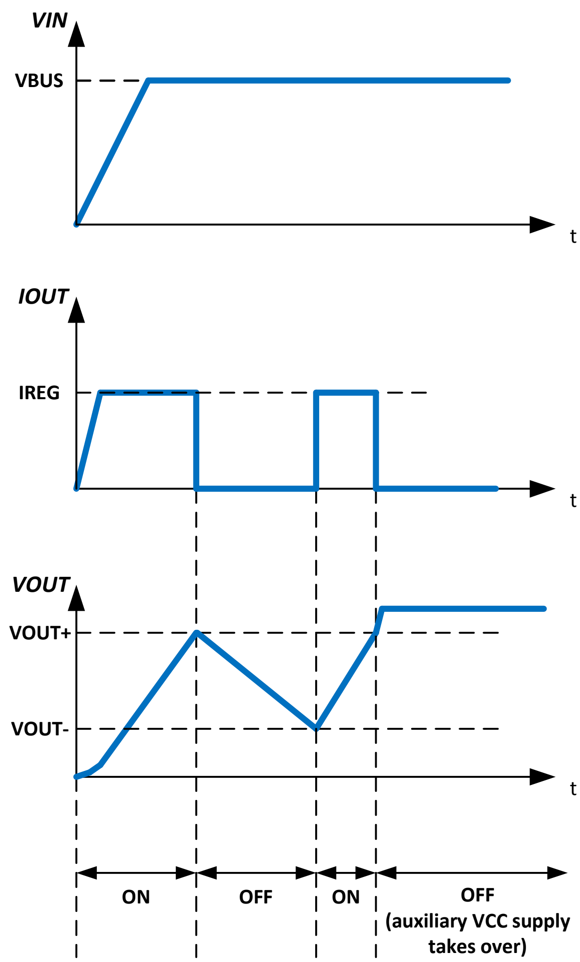

Figure 2: IRS25751 timing diagram.

3. Programming VOUT+

The IRS25751 includes a programmable upper turn-off VOUT+ threshold and a fixed lower turn-on VOUT- threshold. The upper turn-off VOUT+ threshold is programmed at the VTH pin with an external resistor divider circuit (Figure 1, R1, R2). The upper resistor of the divider circuit (R1) is connected from the VOUT pin to the VTH pin. The lower resistor of the divider circuit (R2) is connected from the VOUT pin to COM. The voltage at the VTH pin is then compared internally to an internal reference voltage of 1.12V. Should the VTH pin voltage exceed this internal reference voltage, the internal current source from the VIN pin to the VOUT pin will turn off. The upper turn-off VOUT+ threshold is therefore programmed using the following equation:

$$VOUT^{+} = \frac{R1 + R2}{R2} \cdot VTH^{+} = \frac{R1 + R2}{R2} \cdot 1.12V$$ **[Eq.1]**

If R1 is fixed (typically 1Meg) and the desired VOUT+ threshold is known, then R2 can be calculated using the following equation:

$$R2 = \frac{R1 \cdot VTH^{+}}{VOUT^{+} - VTH^{+}} = \frac{R1 \cdot 1.12V}{VOUT^{+} - 1.12V}$$ **[Eq.2]**

The tolerances of the VTH+ threshold, the resistor divider, and the final VOUT level from the auxiliary supply, should all be considered during the calculation. The final VOUT level from the auxiliary supply must *always be higher* than the turn-off threshold of VOUT+. This will ensure that the IRS25751 turns-off reliably when the system starts and the auxiliary VCC supply takes over.

4. Over-Temperature Protection

The IRS25752 includes an internal over-temperature protection circuit for protecting the IC against excessive power loss and overheating. If the external VCC auxiliary supply of the system does not properly take over and increase VCC above VOUT+, then VOUT will decrease again to the lower turn-on threshold (VOUT-) and the IC will turn on again. The internal current source from VIN to VOUT will charge the VCC supply capacitor up again and turn off again at VOUT+. VOUT will continue to ramp up and down and the internal current source will turn on during each ramp up time. This will cause excessive power losses to occur in the HVFET and will cause the IC junction temperature to increase. Should the IC junction temperature exceed 155degC, then the IC will shut down and the internal current source from VIN to VOUT will turn off. When the IC junction temperature decreases again below 100degC (and VOUT is less than VOUT+) then the IC will become enabled again and the internal current source from VIN to VOUT will turn on again. The IC will continue to operate in and out of ON, OFF and over-temperature protection modes until the VCC auxiliary supply properly takes over or the system is shutdown. For small CVCC capacitor values (i.e. 1uF), VOUT will charge up quickly so the power losses will not be too high. For larger capacitor values (i.e. 100uF), VOUT will charge up slower so the power losses could be excessive and cause the over-temperature to be triggered. The triggering of OTP depends on the maximum ambient temperature conditions of the system, the CVCC capacitor value and ramp up time, and, the programmed VOUT+ level. All of these variables should be carefully considered during the design of the VCC supply and HV start-up circuit.

5. ENN Pin

The IRS25751 includes an ENN pin that can be used to externally enable or disable the IC. The ENN pin is compared internally to a 1.2V threshold voltage. Should the voltage at the ENN pin exceed this threshold then the IC will become disabled and the internal IREG current source will turn off. Depending on the state of VOUT (charging or discharging) the functionality of the ENN pin can differ slightly. In particular, the following two conditions should be considered:

1) If the VOUT pin voltage is charging up and the ENN pin is transitioned from COM to above the 1.2V threshold, then IREG will turn off and VOUT will start to discharge. If ENN is then transitioned back down to COM then IREG will turn on again and VOUT will continue charging again (Figure 2).
2) If the VOUT pin voltage is discharging and the ENN pin is transitioned from COM to above the 1.2V threshold, then IREG will remain off and VOUT will continue discharging. If ENN is then transitioned back down to COM then IREG will remain off and VOUT will continue discharging.

Please note: If it is desired to turn the internal IREG current source on again during the time when VOUT is discharging and before VOUT has reached VOUT-, then the VTH pin should be pulled momentarily to COM and then released. This will cause VTH to go below the internal 1.14V threshold causing IREG to turn on again before VOUT has reached VOUT-.

Finally, if the ENN pin is not being used then it should be connected directly to the COM pin of the IC.

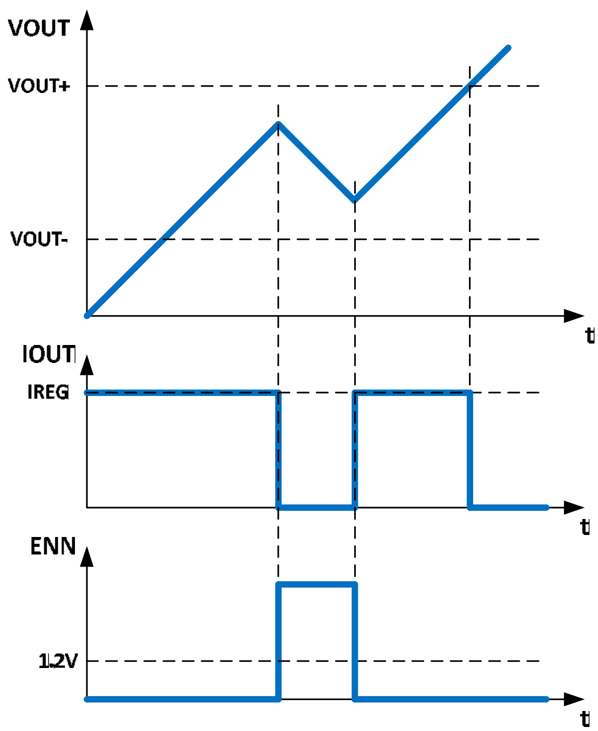

Figure 2: ENN pin timing diagram.

6. Application Example

A 90W boost PFC circuit was used to demonstrate the functionality of the IRS25751 for starting the circuit up when the mains AC voltage is first applied at the input. The VIN pin of the IRS25751 is connected to the rectifier output voltage node (Figure 3) and the VOUT pin is connected to the VCC node of the boost PFC control IC (IRS2505, VCC pin 3). The programming resistor values are selected as 1Meg for the upper resistor (R3) and 90.9K for the lower resistor (R4) which gives approximately 13.4V for the VOUT+ turn-off threshold (using [Eq.1]). The IRS2505 boost PFC control IC has a maximum VCCUV+ turn-on threshold of 12.0V, so the selected level of 13.4V for VOUT+ should be a safe margin above VCCUV+ to ensure that the circuit turns on reliably.

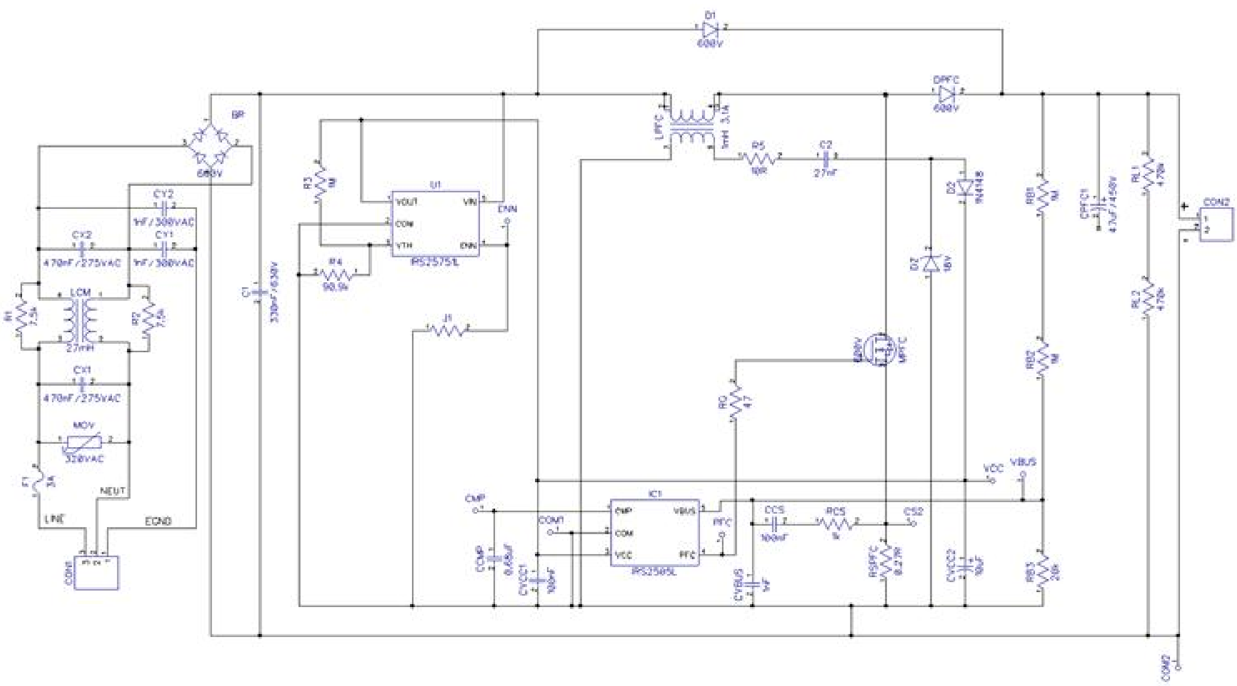

Figure 3: Boost PFC application circuit using IRS21571 for start-up.

The start-up time waveforms (Figure 4) show the IRS25751 compared with a standard method using resistors. The IRS25751 gives a 43% reduction in start-up time (at 230VAC) and turns off properly after VOUT+ is reached. The secondary winding takes over as the auxiliary supply and provides the necessary operating current to VCC through diode D2. The IRS25751 also gives a slight increase in overall system efficiency (Figure 5) since the resistor method consumes losses continuously and the IRS25751 turns off after start-up. Finally, the standby losses will also be significantly lower due to ultra-low current consumption during the off state of the IRS25751.

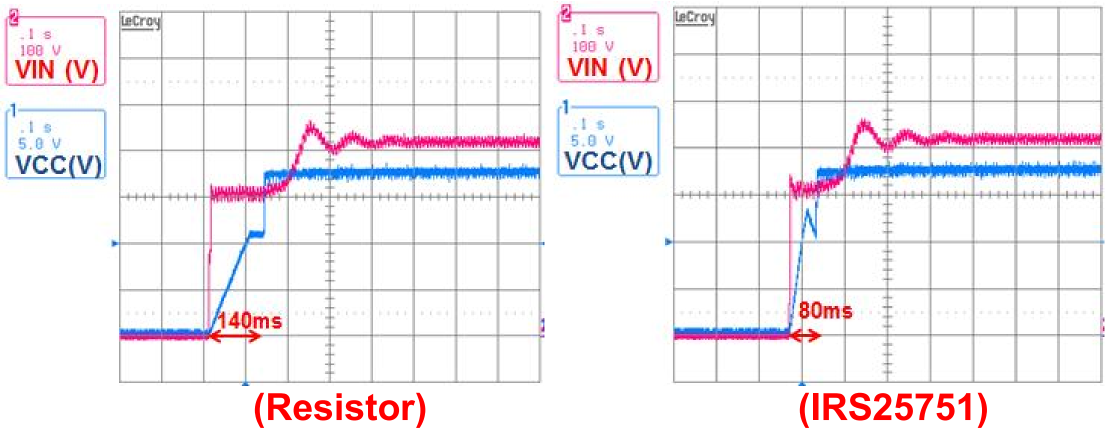

Figure 4: Start-up waveforms for IRS25751 vs. resistor method (240kOhm). (VIN=red trace, VCC=blue trace, CVCC=10uF)

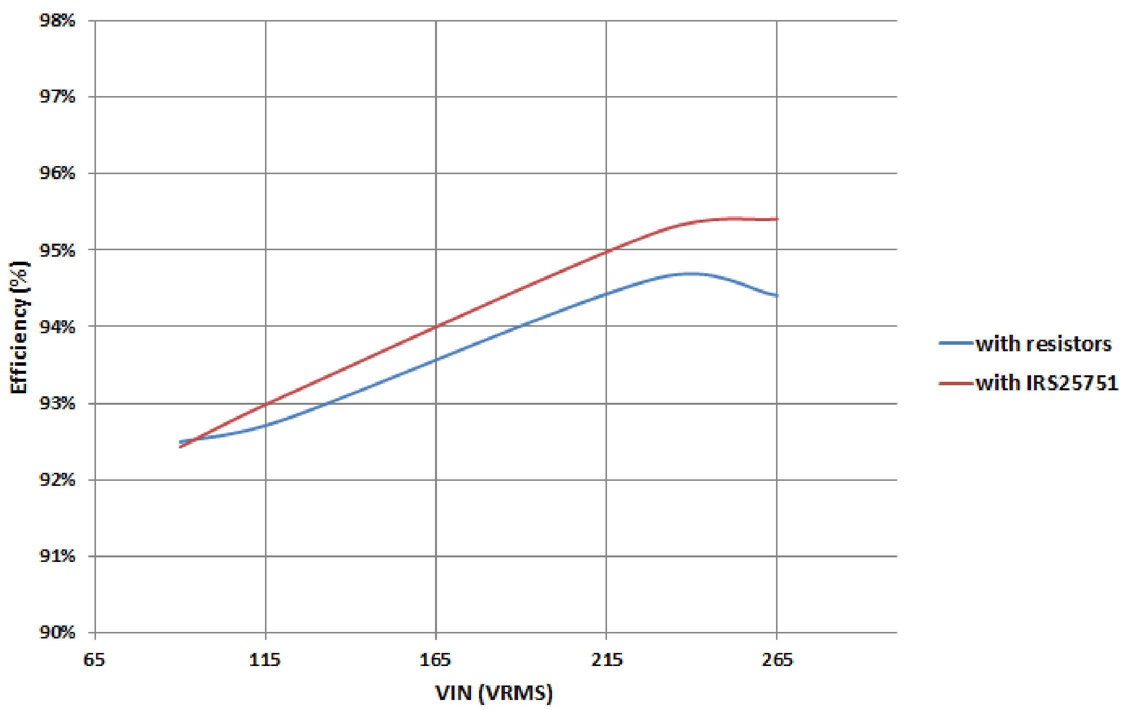

Figure 5: System efficiency comparison (90W boost PFC circuit).

7. PCB Layout Guidelines

For correct circuit functionality and to avoid high-frequency noise problems, proper care should be taken when designing the pcb layout. Design problems due to poor layout can typically include high-frequency noise, EMC issues, latch-up, abnormal circuit behavior, component failures, low manufacturing yields, and/or poor reliability. The following PCB layout guidelines should be followed as early as possible in the design cycle in order to minimize circuit problems, shorten design time, and increase reliability and manufacturability:

1) Do not connect the IRS25751 COM to the power ground of the system. Connect the IRS25751 COM pin to the VCC ground of the system. This will prevent high-frequency noise from occurring on IC pins that can cause circuit malfunction or failures.
2) Place the VOUT pin close to the VCC supply capacitor of the system. This will help reduce possible noise at the VOUT pin and VTH pin.
3) Place the IC programming resistors as close as possible to the VOUT, VTH, and COM pins of the IC.
4) Do not route PCB tracks underneath the IC! The small SOT-23 package of the IRS25751 has a given creepage distance between the pins that is required to safely block high voltages between the VIN pin and the other pins. Placing traces underneath the IC will reduce the effective creepage distance between the pins.
5) If the ENN pin is not being used then connect it directly to the IC COM pin.
6) See **Figure 6** for surface mount pcb layout guidelines.

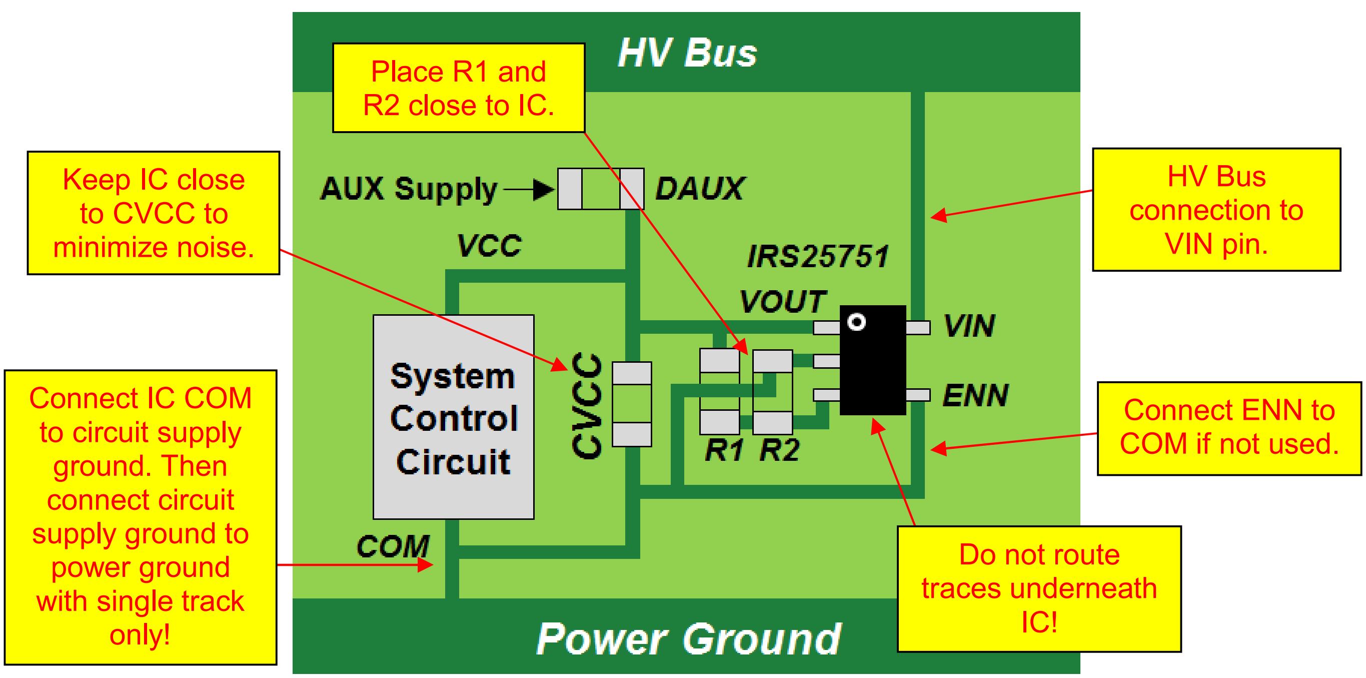

Figure 6: IRS25751 surface-mount PCB layout example (Bottom View).

8. Conclusions

The design information presented here will greatly help during the design of the new IRS25751 high-voltage start-up circuit and will help reduce potential problems. Ease of understanding and using the IC, programming, avoiding excessive temperatures, and proper PCB layout guidelines, will all help minimize design time, maximize performance, and maximize manufacturability and robustness of the final design.